The PID control algorithm

The following is a brief description of the standard PID control algorithm used in most controllers.

Proportional Contol (gain)

The first element of PID control to be developed is Proportional control. The equation is simple:

error = measurement - setpoint (direct action)

or

error = setpoint - measurement (reverse action)

Note the action may be either direct or reverse. In a direct acting control loop an increase in the process measurement causes an increase in the ouput to the final control element.

The proportional only equation is:

output = gain x error + bias

The bias is sometimes known as the manual reset. Some control systems (such as Foxboro products, use proportional band rather than gain. The proportional band and the gain are related by:

$$\text{Gain} = \frac{100\%}{\text{Proportional Band}}$$

$$\text{Proportional Band} = \frac{100\%}{\text{Gain}}$$

Gain is the ratio of the change in the output to the change in the input.

$$\text{Gain} = \frac{\text{Output change}}{\text{Input change}}$$

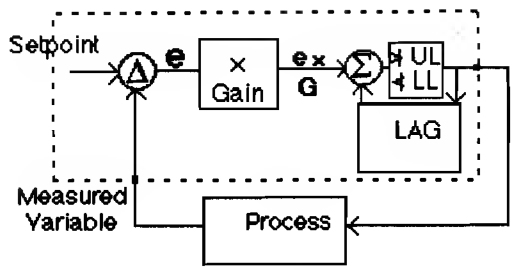
Proportional band is the amount the input would have to change in order to cause the output to move from 0 to 100% (or vice versa)

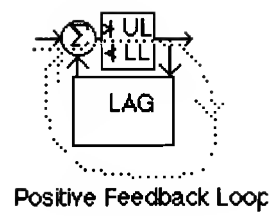
With proportional only control the controller will not bring the process measurement to the setpoint with out a manual adjustment to the bias (or manual reset) term of the equation. In the early days of control the operator, upon observing an offset in the control loop would correct the offset by manually "reseting" the controller (adjusting the bias).

Integral Control (automatic reset)

Rather than to require that the operator "manually reset" the control loop whenever there was a load change control functions were developed to "automatically reset" the controller by adjusting the bias term when ever there was an error. This "automatic reset" is also known simply as "reset" or as "integral".

The most common way to implement integral mode in analog controllers is to use a positive feedback into the output.





The equation for PI control is:

$$\mathbf{Out = g \times K_r \times \int e \; dt}$$

out = gain x (error + integral(error)dt)

The amount of reset used is measured in terms of "reset time" in minutes or its inverse, "reset rate" in repeats per minute. The following test can be perfored on a controller which is not connected to the process:

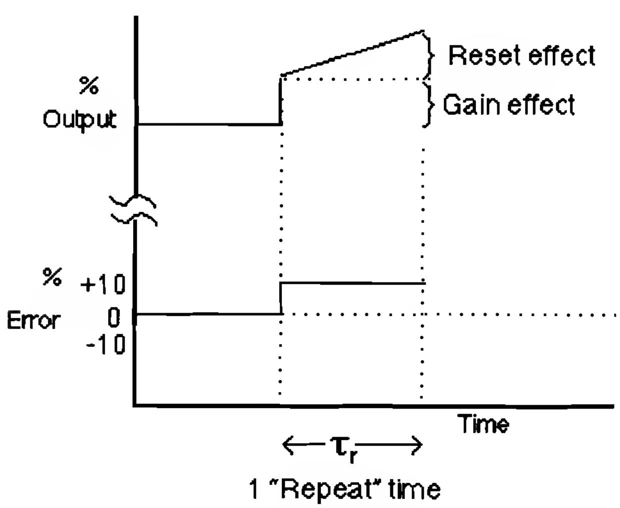
1. an adjustable signal is connected to the input.

2. the output is indicated or recorded.

3. wtih the controller manual the setpoint and the input are set to the same value.

4. the controller is switched to automatic. Becuase the error is zero, the output does not change.

5. The input to the controller is changed by a small amount. The output will move suddenly due to the gain. The output will continue to change at a constant rate. The time is measured from the time of the intitial change until the time that the instant change is repeated by the constant movement. The repeat time, or reset time, is the time it takes for the reset effect to repeat (or move the output the same amount as) the gain effect. Its inverse is reset rate, measured in repeats per minute.



Derivative Control (Pre-Act tm or Rate)

The third term of PID control is derivative, also known as Pre-Act (trade mark of Taylor Instrument Companies (now ABB Kent Taylor), and rate.

The derivative term looks at the rate of change of the input and adjusts the output based on the rate of change. The derivative function can either use the time derivative of the error, which would include changes in the setpoint, or of the measurement only, excluding setpoint changes.

The equation for the derivative contribution (assuming derivative on error) is:

Out = g x K_d x \F(de,

The amount of derivative used is measured in minutes of derivative. To illustrate the meaning of minutes of derivative, consider the following open loop test:

1. Connect a signal generator with a ramp cability to the input of a controller. The controller output is connected to a recorder. Configure the controller with some gain, no reset, and no derivative.

2. With a constant output from the signal generator and the controller in manual, adjust the setpoint to be equal to the input from the signal generator.

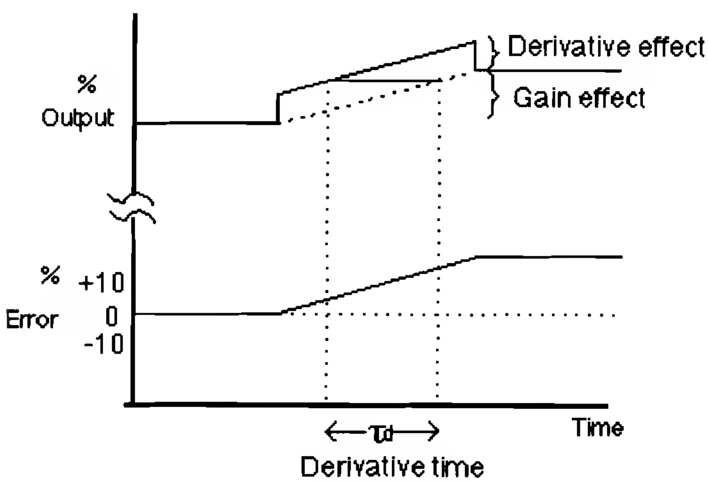
3. Place the controller into automatic mode.

4. Start the ramp.

5. Later stop the ramp.

6. Repeat the above steps with some derivative. Compare the trend records of the controller's input and output.

On the following trend record



note that when the ramp is started, with no derivative (dashed line) the output ramps up due to the change in input and the gain. Using derivative (solid line) the output jumps up, rises in a ramp, then jumps down. The difference ***in time*** between the solid line and the dashed line represents the amount of derivative, in units of time (usually minutes).

Putting it together: PID control

Combining the three elements, gain, integral, and derivative, we have the equation:

$$\mathbf{Out = G\left(e + R\int edt + D\frac{de}{dt}\right)}$$

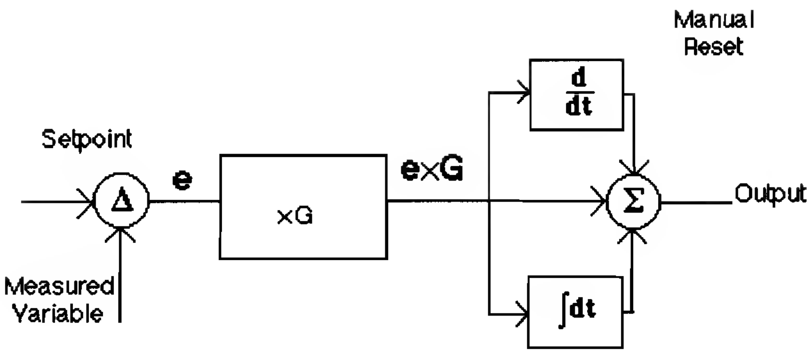
Where

G = Gain

R = Reset (repeats per minute)

D = Derivative (minutes)

Shown graphically:



Note that in the equation the gain is multiplied by all three terms. This is important for the PID equation to be able to be tuned by any of the standard tuning methods.

Simple program for PID implementation

Updated Februrary 1, 1996.
Provided by John Shaw.
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